RADAR RANGE-GATED MTI PROCESSOR

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NAVAL POSTGRADUATE SCHOOL
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THESIS

RADAR RANGE-GATED MTI PROCESSOR

by

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Radar Range-Gated MTI Processor

by

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ABSTRACT

Twenty range-gated channels and the associated timing circuits were constructed for implementation of a moving-target indicator (MTI) by range-gates and filters (RGF). Improvement over existing systems was accomplished by simplification in the range-gated channels. Elements of the system include both discrete and integrated circuits. A design objective was to achieve reliable and jitter-free gating pulses with timing flexibility. Performance of the system was tested in conjunction with the AN/UPS-1 air search radar.

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I. INTRODUCTION

In most doppler radars the main purpose is to detect moving targets on the basis of their doppler frequency shift and eliminate stationary targets. The doppler frequency shift associated with moving targets may be used in radars to enhance the visibility of moving targets in the presence of stationary targets. Moving-target indicator (MTI) radars employ the doppler shift in an otherwise conventional pulse radar to improve subclutter visibility, the maximum value of the ratio of the echo power from a fixed targets to the echo power from a moving target at the same range and bearing for which the moving target can still be detected. MTI processing increases the ratio of the amplitude of moving-target echos to the amplitude of echos from fixed targets (clutter).

Discrimination between the stationary and the moving targets is obtained by determining the change in phase of successive echos from a given target in a sequence of pulses. Any target moving with a relative radial velocity with respect to the radar will present a frequency shift in the reflected signal, and hence a progressive change of phase. The formula for the frequency shift is given by

$$f_d = \frac{2\, v_r}{\lambda}$$

f_d = Doppler frequency shift

v_r = Relative (or radial) velocity of target with respect to radar

λ = Radar wavelength

If f_d is in cycles per second, v_r in knots, and λ in centimeters,

$$f_d = \frac{103\ v_r}{\lambda}$$

Moving targets such as aircraft, ships, and land vehicles generally have higher radial velocities relative to a fixed radar than those of stationary or near stationary targets such as terrain, clouds, sea waves, vegetation, etc. It seems obvious that the clutter can be reduced by providing for each element of range some sort of frequency discrimination that will eliminate the unshifted frequency components while passing those whose frequency has been changed.

The filtering may be accomplished by heterodyning fixed signal components to zero frequency. Pulse signals in the video amplifier will be unmodulated in amplitude for fixed targets, and modulated at the doppler frequency for moving targets.

However, there are also some complicating factors which must be taken into account.

First, rotation of the antenna will amplitude modulate all returned signals. This spreads out the spectrum of all signals including clutter by an amount depending on antenna beamwidth and the speed of rotation. Thus the clutter spectrum is not concentrated entirely at zero frequency, but is spread over a finite band of low frequencies.

Second, certain clutter signals such as vegetation and ocean waves have additional frequency spread due to incidental clutter motion. This frequency spread is a function of the type of clutter and wind velocity. Because of the finite bandwidth of clutter return due to these two factors, it is desirable that the clutter filter eliminate a band of frequencies about zero frequency. Ideally the width of this rejection band should be adjustable to accommodate a range of antenna rotation rates and a range of clutter characteristics.

The transmitted spectrum of a pulse radar consists typically of some thousands of components on each side of the carrier frequency with a spacing equal to the pulse repetition frequency. Each line of the received spectrum suffers from spreading due to the two effects mentioned above. In addition the lines of the received spectrum of a moving target are all shifted by the doppler frequency. If the frequency components are translated by subtracting the carrier frequency, a typical video spectrum is obtained as shown in Figure 1. One method of eliminating the clutter spectrum is then to employ a comb filter with a transmission characteristic as shown by the dashed lines.

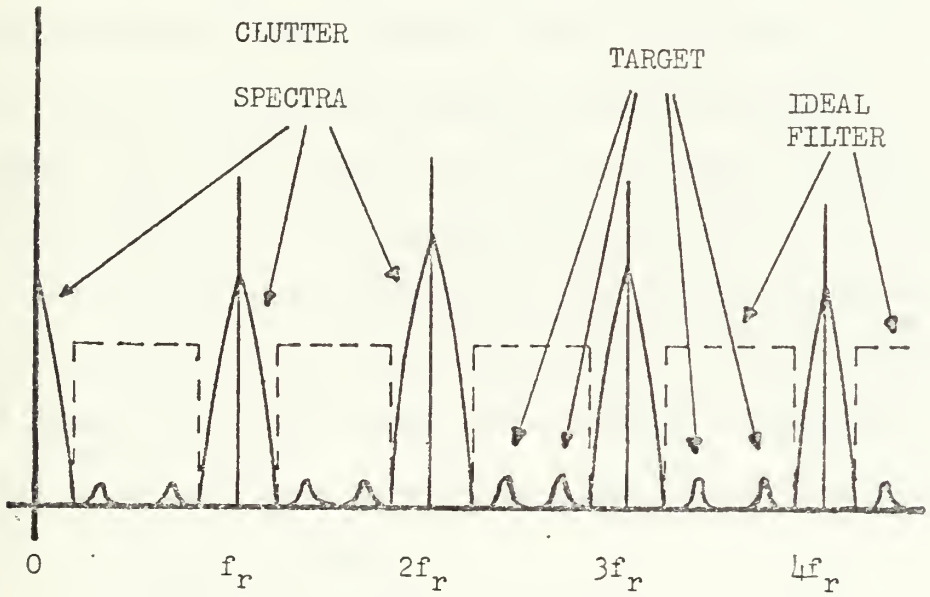


Figure 1. Pulse-radar video spectrum.

The traditional method of obtaining a comb filter is to use a delay-line canceler. A second method with several inherent advantages is to employ range gates with band-pass filters. These methods are discussed in the next section.

II. MOVING-TARGET INDICATORS

A. DELAY-LINE CANCELERS

In an MTI delay-line canceler the bipolar video signal is injected into a delay line. Video pulse signals from moving targets are amplitude modulated at the doppler frequency or at $(Nf_r \pm f_d)$ where N is an integer, f_r = pulse repetition frequency, and f_d = doppler frequency, and the value of N and the sign is such that the modulation frequency is between 0 and $f_r/2$. The successive pulse returns from the fixed targets have constant amplitude, except for variation due to antenna scanning and incidental clutter motion. Successive pulse echos from any given target are separated in time by the pulse repetition period of the radar in use. The delay channel of the canceler introduces a delay which is exactly equal to the pulse repetition interval of the radar. Thus if the output of the delayed channel is subtracted from the output of the undelayed channel, fixed target clutter is very materially reduced, whereas for moving targets pulse-to-pulse cancellation normally does not occur since successive pulses generally are of different amplitude due to doppler modulation.

The simplified block diagram of the single delay-line canceler is shown in Figure 2.

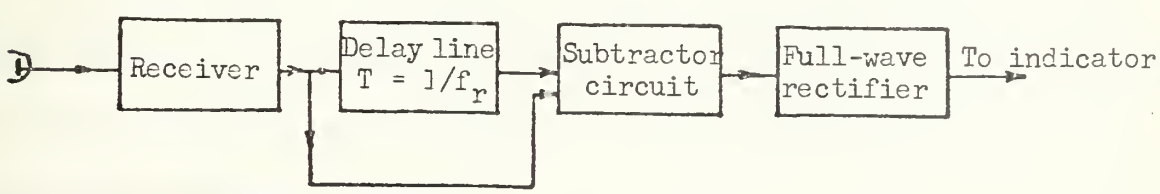


Figure 2. Single delay-line canceler

Although the single delay-line canceler is simple in concept it does not show the characteristics of an ideal comb filter. The frequency transfer characteristic may be shown to be in the form of a rectified sine wave as indicated by the solid curve of Figure 3.

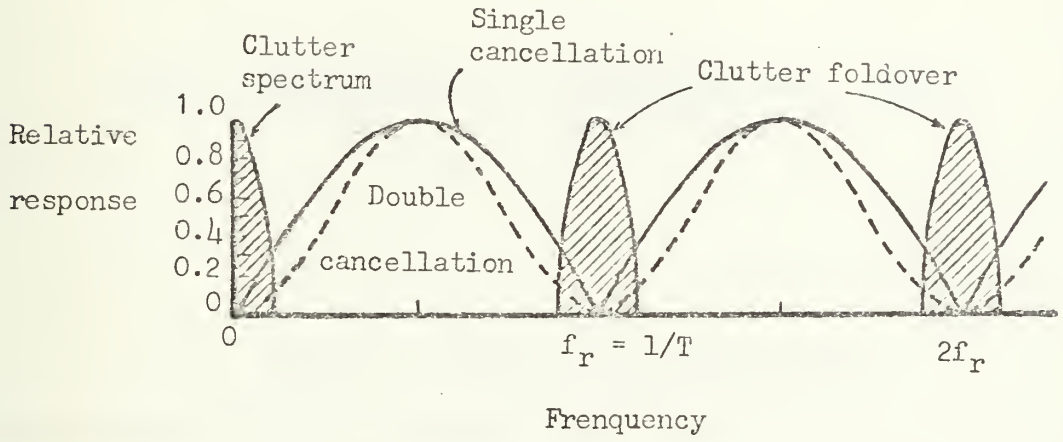


Figure 3. Characteristic response of a DLC

If the moving target doppler frequency shift is equal to any multiple of the pulse repetition frequency, $(Nf_r - f_d) = 0$ and cancellation occurs as for fixed targets. A target speed which causes this effect, with the doppler shift equal to any multiple of the pulse repetition frequency, is called a blind speed.

The delay-line cancelers, the delay time is usually long (on the order of millisecond or more) due to low radar pulse repetition frequency, usually less than 1000 Hz. To provide this long delay, acoustic delay lines are generally used.

To improve clutter cancellation, double delay-line cancelers can be used, Figure 4. The frequency response of the double delay-line canceler is shown in dashed lines in Figure 3. The main drawbacks of the double delay-line cancelers are the cost, the complexity, and the size of such

a system, and the fact that the filter characteristics are still far from ideal. Improved frequency response can be obtained by using multiple

Figure 4. Double delay-line canceler

delay lines at greatly increased complexity.

The basic disadvantages of the delay-line cancelers are high insertion loss of the delay line (35 to 70 dB), temperature dependence of delay, the tendency to introduce some spurious signals due to multiple reflections, degradation of signal-to-noise ratio, amplitude variation of moving-target echos due to the variation of gain with frequency, complexity and complete breakdown of the system because of a failure of any one of many elements in the system. Since the delay time is fixed when the delay line is constructed, this also fixes the pulse repetition frequency of the radar. This prevents the use of a variable PRF to eliminate blind speeds unless delay lines of different lengths are employed.

B. RANGE-GATED MTI

MTI by range-gating and filtering (RGF) is another method of implementing a moving-target indicator system. This method gives greatly improved frequency response as compared to a delay-line canceler, and

vastly improved reliability. The main disadvantage has been the circuit complexity, large size, high power consumption, and the cost of the system. The advent of semiconductor technology and subsequent microminiaturization has helped to overcome these obstacles, and has opened new methods of investigation and research in this area.

As has been seen the doppler frequency of any moving target is reduced to half the pulse repetition frequency or less in the video amplifier. Hence a band-pass filter with a lower cut-off frequency above the maximum clutter frequency and an upper cut-off frequency less than the PRF of the radar might well be used to pass the doppler information while eliminating fixed target clutter. There are important limitations to this technique.

First, by its nature the narrow-band filter degrades the range information contained in the return signal. Second, signals from moving targets at all ranges could enter the filter.

Range gates may be employed to separate target echos on the basis of their different times of arrival for different ranges. Signals in the various range gates may then be applied to separate filters. Range information is therefore not lost, and interference between targets at different ranges is eliminated. A band-pass filter follows each range gate to eliminate clutter while passing signals due to moving targets.

There are important advantages to this scheme over the delay-line canceler. Since large numbers of channels are operated in parallel, if any one of them fails very little information is lost. Overall system reliability is high. Cancellation of clutter can be achieved by using more nearly ideal filters since greater flexibility of filter design is available for simple band-pass filters than for comb filters. With

special integrated circuits a range gated MTI radar should be no longer physically larger nor consume more power than an MTI radar employing a delay-line canceler. It should be relatively easy to eliminate blind speeds with range-gated MTI by using random pulse repetition periods, while with delay-line cancelers it is difficult to use even two pulse repetition periods, and this only partially eliminates blind speeds.

Several range-gated MTI radars have been built at different locations. Although there have been much difference in detail, the basic operation has been the same for all.

III. OBJECTIVES

There were two prime objectives of this work. The first was to design and build 20 range-gated channels, to combine these channels in an operating system and test them as part of a modified UPS-1 radar. The second objective was to design, build, and test reliable, jitter-free timing circuitry which could be synchronized with the radar pulse repetition period to obtain gating pulses for the input and output circuits of the 20 channels. An important part of this objective was to achieve circuits that will function with a jittered pulse repetition period. It was also desired to be able to vary the spacing between the gates so that the effect of the gate spacing on radar performance could be investigated experimentally. All solid state components and integrated circuits were used. Considering existing methods, simplifications and improvements were made wherever possible.

An AN/UPS-1 air search radar was chosen as the basic MTI radar to which the range-gated MTI was to be adapted. Some characteristics of this radar are given in Table 1.

Because of the impractibility of constructing all of the channels required for the full 80 nautical mile range of the radar during the time available for this work, only 20 channels were constructed. Four test channels and the timing circuitry were first built to permit thorough tests of the circuits, and then the balance of the 20 channels were constructed.

In the next section system description and experimental procedures are discussed in detail.

AN/UPS-1 Air Search Radar

PRF (cps)	Pulse Width (sec)	Antenna Pattern	Antenna rotation rate	Carrier Frequency (MHz)	Pulse Power
800	1.4	Horizontal 3 dB beamwidth of 2.5 degrees	5 rpm. typically	1200	1 nw

Table I. Some characteristics of AN/UPS-1 air search radar

IV. SYSTEM DESCRIPTION, DESIGN, AND OPERATION

The system block diagram is shown in Figure 5. In a range-gated MTI the radar return is passed through RF, IF, and phase sensitive detection circuits. A bipolar video signal is thus obtained in conventional manner. This video signal is applied to each of the 20 range channels. The outputs of these channels are combined to form a reconstructed video signal for the range interval covered by these 20 channels.

In the test system the video signal may be compared with that obtained through the parallel delay-line canceler in the UPS-1. The resulting signal (MTI video) is displayed on a PPI scope. The timing circuitry provides successive gating pulses to the channels in synchronization with the radar PRF so that one after the other is enabled in turn. The timing circuitry is activated by the radar trigger. The width of each successive pulse is nominally 0.7 microseconds, but may be varied from 0.1 to 1.4 microseconds to test the effect of the channel time separation on system operation. The spacing between pulses equals the pulse width. Thus successive channels receive a portion of the bipolar video signal corresponding to successive range intervals. Therefore each channel contains for a short range interval target, clutter, and noise information. This signal is filtered to eliminate clutter, rectified, integrated, and a pulse formed to represent the amplitude of the remaining signal at that range interval. By summing the outputs of several channels the clutter-free MTI video signal is obtained, and finally this information is displayed on a scope.

The following section discuss individual circuits in detail.

A. RANGE GATES

1. Sample-and-Hold Circuit

The purpose of the sample part of the sample-and-hold circuits is to separate the video signal into time (range) increments. Thus it is possible to pass the signal through narrow-band filter without any lose of range information. This process is called range gating. The width of the range gates depends upon the range accuracy desired, this is in turn related to the IF bandwidth and to the complexity which can be tolerated. The gate interval is usually of the order of the transmitted pulse width. Thus range resolution is equal, at best, to the width of the sampling pulse.

The sample between pulses is held on a capacitor for one period. The reason for holding the sample is that by stretching the pulse to the full period the lowest frequency component is emphasized, while the high-frequency components, which carry no significant information, are suppressed.

For proper operation of the circuit, the charging time constant should be less than the width of the sampling pulse so that there will be adequate time to charge the hold capacitor to the signal level during the sampling period. This necessitates a gate with very low resistance when on. The resistance should be very high when not sampling. A small hold capacitor can then be used to minimize the time constant.

One of the most important criteria is choosing a gate was to obtain a circuit which would operate essentially with zero offset voltage. In other words the gating pulse itself should not appear as a pedestal at the output.

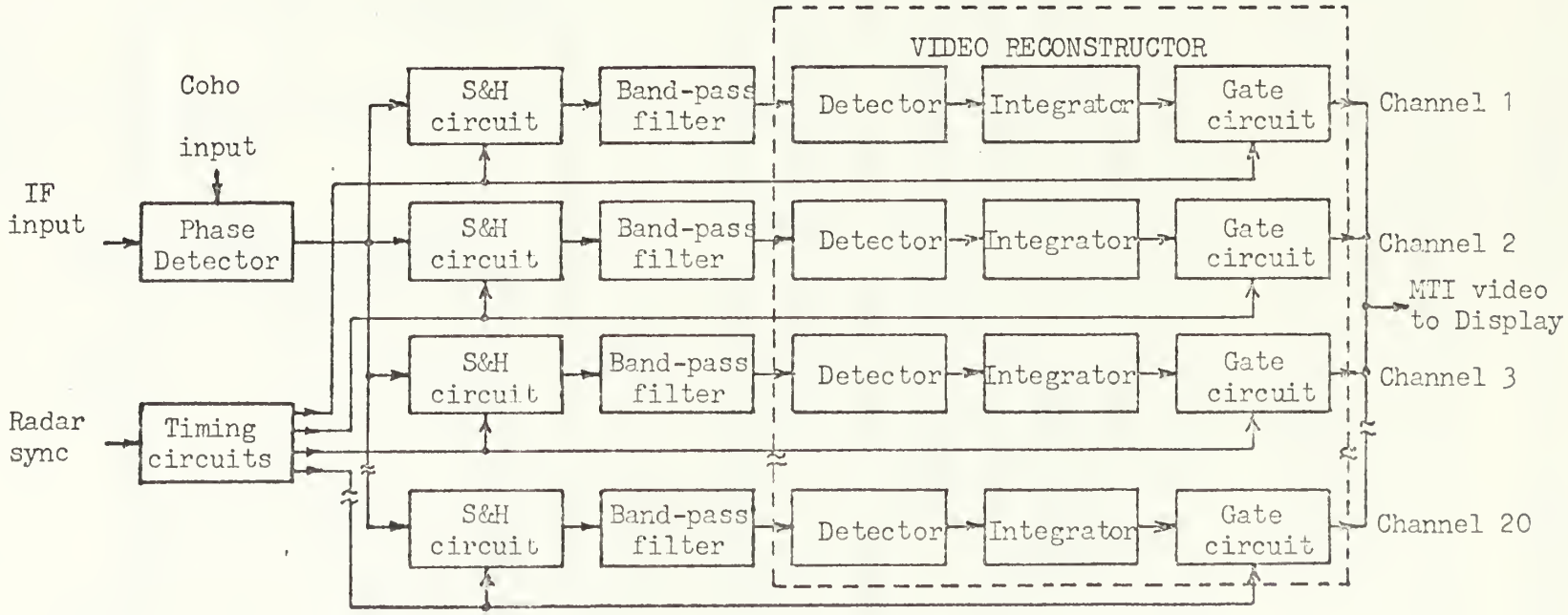


Figure 5. MTI by range gates and filters, block diagram

The other important point was to obtain gate operation with short sampling times. Switching times in the low nanosecond range were necessary.

Sampling frequency must be more than twice the desired video bandwidth. Video bandwidth in conventional pulse radars is more than half the IF bandwidth so that the system bandwidth is determined in the IF amplifier.

If $BW_{IF} = 1.2/\tau$, then pulse repetition rate should be more than $1.2/\tau$, or the pulse spacing must be less than $\tau/1.2$.

In a coherent radar the system bandwidth might be set in the video- e.g. by the sampling rate- and a somewhat wider IF bandwidth use. This would minimize the number of channels required.

All transitors, diodes, and FET's used in construction of the unit are high-speed, low switching-time devices.

The circuit diagram of the sample-and-hold circuit is shown in Figure 6.

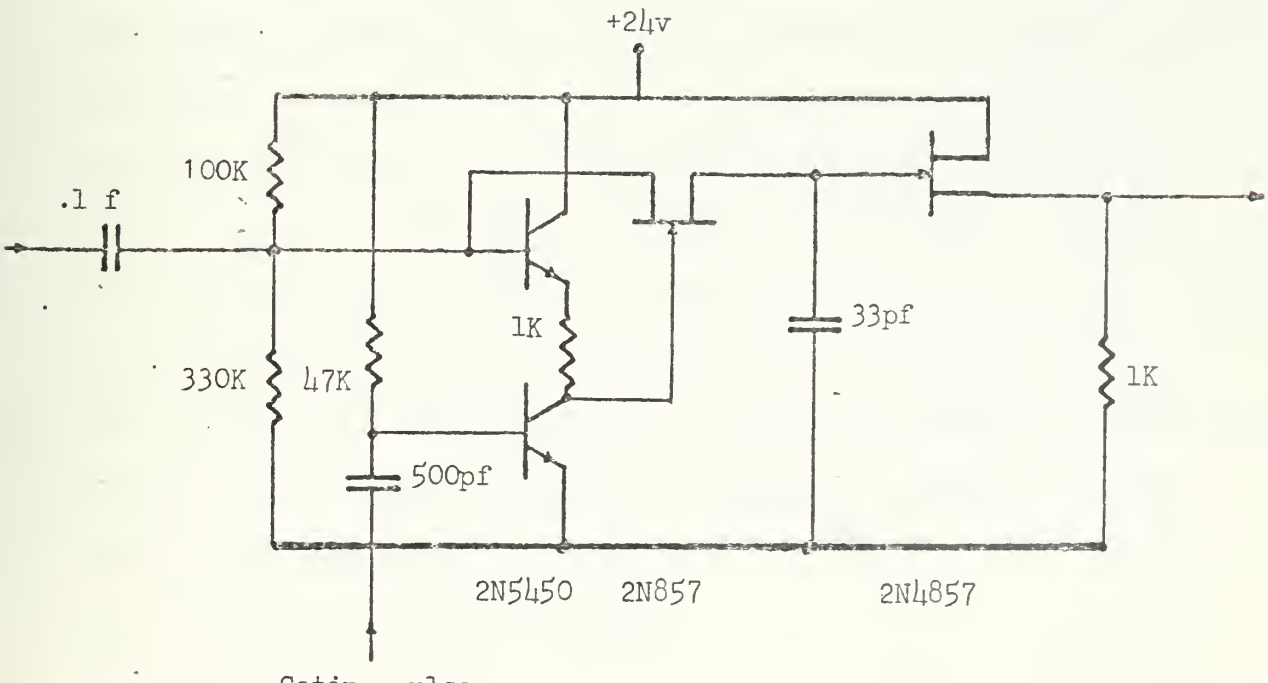


Figure 6. Sample-and-hold circuit

2. Filter Circuit

The heart of the system is the band-pass filter which allows the doppler frequencies from moving targets to pass, but which eliminates the dc and low frequencies associated with stationary targets.

Frequency response of the desired filter is shown in Figure 7.

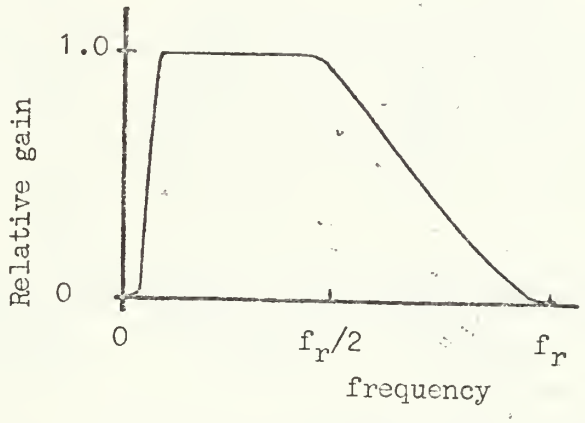


Figure 7. Frequency response of the band-pass filter

The lower cut-off frequency should be just above the highest fixed-target frequency. Since the clutter spectrum is not constant due to adjustable speed of rotation of the antenna and to the variation of clutter spectrum with wind speed and type of scatterers, it is most desirable to make the width of the rejection band adjustable. Response should be uniform from the cut-off frequency to one half of the pulse repetition frequency (PRF) of the radar in use. Attenuation should be high at and beyond a frequency equal to the pulse repetition frequency minus the highest clutter component, see Figure 1. Varying the pulse repetition frequency might sometimes be desirable also. Thus the pass-band of the filter should be variable.

The filter employed is an active filter the circuit of which is shown in Figure 8. In the present configuration the low-frequency cut-off is fixed at 50 Hertz.

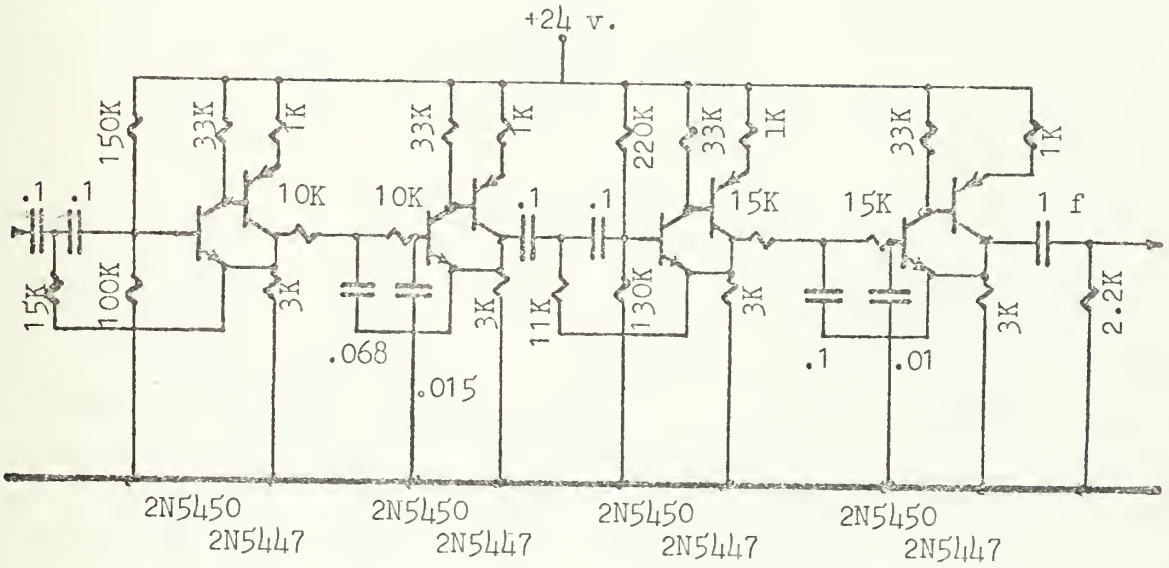


Figure 8. Synthesized band-pass filter circuit diagram

The most critical elements of the circuit are the capacitors and an equal number of resistors. All 5% tolerance resistors were used. When 10% capacitors had to be used in some cases the associated resistor values were adjusted accordingly to obtain the desired performance. In construction of this circuit the most difficult part was to obtain the desired high-precision components from the market.

The experimental response characteristics of this circuit is shown in Section VI, Figure 21. The lower cut-off frequency is 50 Hz, while the upper cut-off frequency is 400 Hz. The filter rejects the frequencies from zero to 45 Hz and has high attenuation above 755 Hz.

3. Video Reconstructor Circuit

The signal out of the band-pass filter is rectified before integration and video reconstruction. The circuit diagram is shown in

Figure 9. The first diode rectifies the negative part of the incoming signal and increases the output signal amplitude. A second parallel diode goes to a small positive potential through an adjustable resistor. The resistors in the several channels are adjusted to equalize the dc levels at the outputs of the several channels.

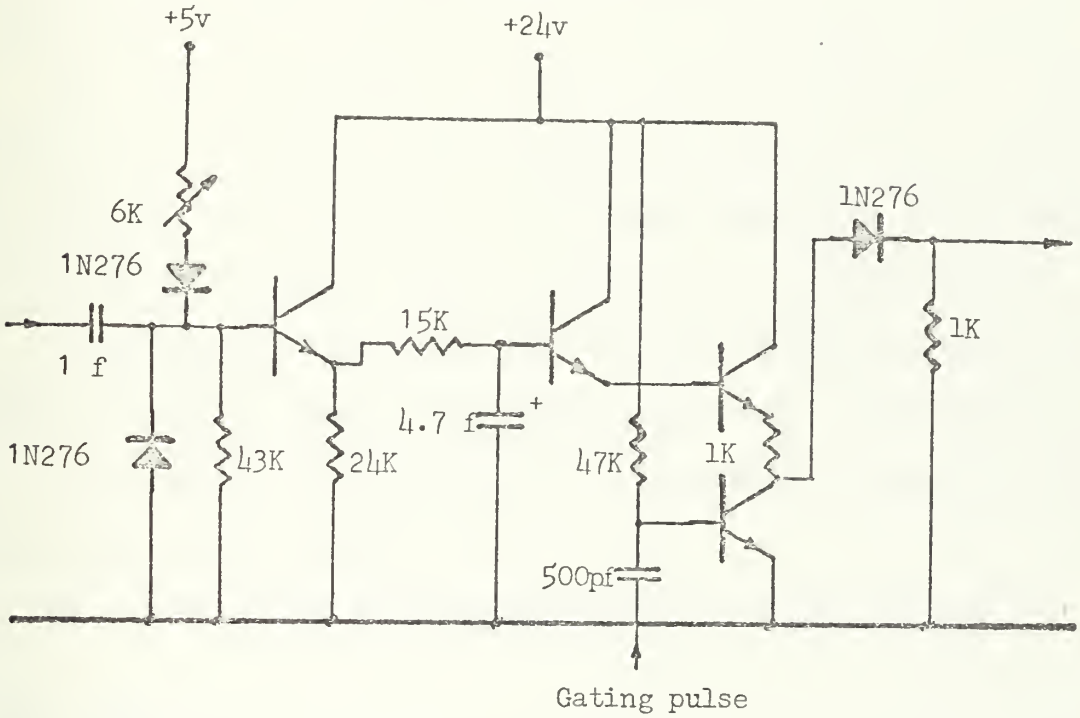


Figure 9. Circuit diagram of rectifier, integrator, and video reconstructor

This signal is integrated by a low-pass filter after detection. This filter has a time constant comparable to the antenna time on the target. More efficient integration is therefore obtained than is obtained by the phosphor of a PPI scope. The ability to detect weak signals is therefore enhanced.

The gating pulse which is common to the sample-and-hold circuit and the video reconstructor circuit forms a pulse at a time corresponding to the channel range with an amplitude proportional to the output of the integrator. A diode is used as the gating device. Now the signal is reconstructed and is ready to be displayed.

The linearity of this circuit is shown in Section VI, Figure 22.

B. TIMING CIRCUIT

Basic requirements determining the design of the timing circuitry are as follows. The first was to provide an adjustable delay after the radar synchronization pulse before the first range gate is enabled.

The second requirement was that the design be such that the circuit can easily be extended to include additional channels in the future.

The third was that the size, cost, and complexity of the circuit was to be held to a minimum, and the circuit was to be highly reliable.

To provide the first requirement a General Radio pulse generator was used to obtain a variable delay that can be preset by the operator.

To satisfy the second and the third requirements integrated circuits were used wherever possible.

The overall timing system block diagram is shown in Figure 10.

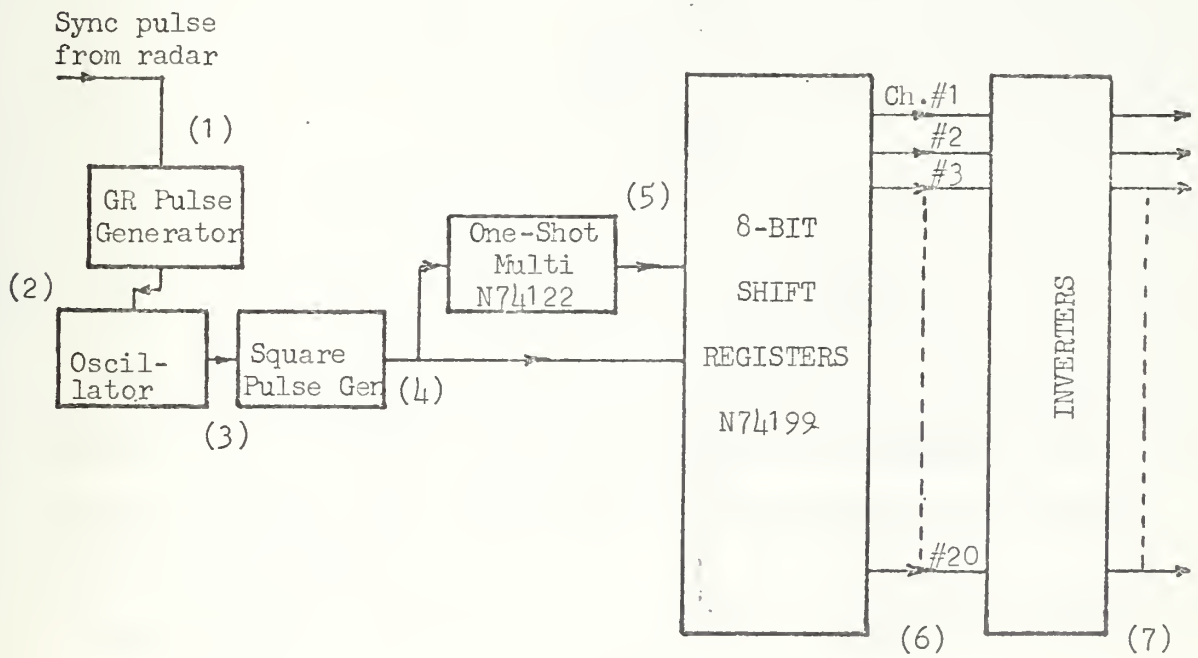


Figure 10. Block diagram of timing circuitry

The input sync pulse from the radar is a positive going rectangular pulse with a period of 1250 microseconds and a pulse width of 14 microseconds. This pulse is fed through the GR pulse generator to obtain the desired delay at the output of this device.

The second step is to provide the necessary clock pulses for the N74122 retriggerable monostable multivibrator and N74199 8-bit shift registers which generate the gating pulses.

The delayed and inverted synchronization pulse from the General Radio pulse generator is fed to an oscillator circuit which oscillates during the negative input gate. The circuit diagram of this oscillator is shown in Figure 11.

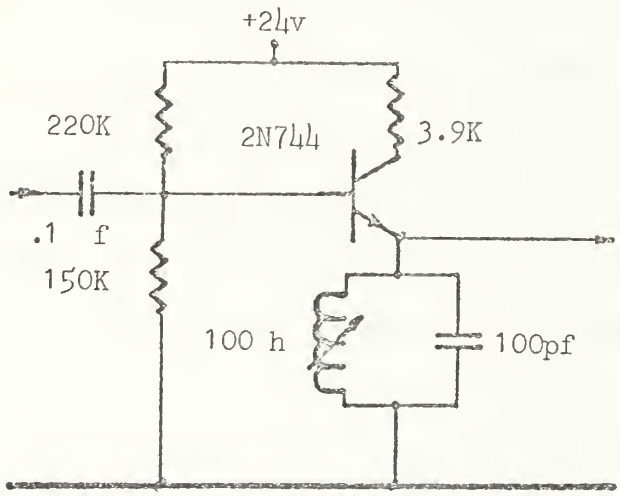


Figure 11. Oscillator circuit diagram

The tank circuit of this oscillator consists of a 100 picofarad mica capacitor and a variable 100 microhenry inductor in parallel. The values of these components are chosen to give a period equal to the desired gating pulse spacing.

The sine-wave signal from the oscillator is then applied to the square pulse generator circuit shown in Figure 12. This circuit is so biased that the cut-off is at zero and saturation occurs at +5v.

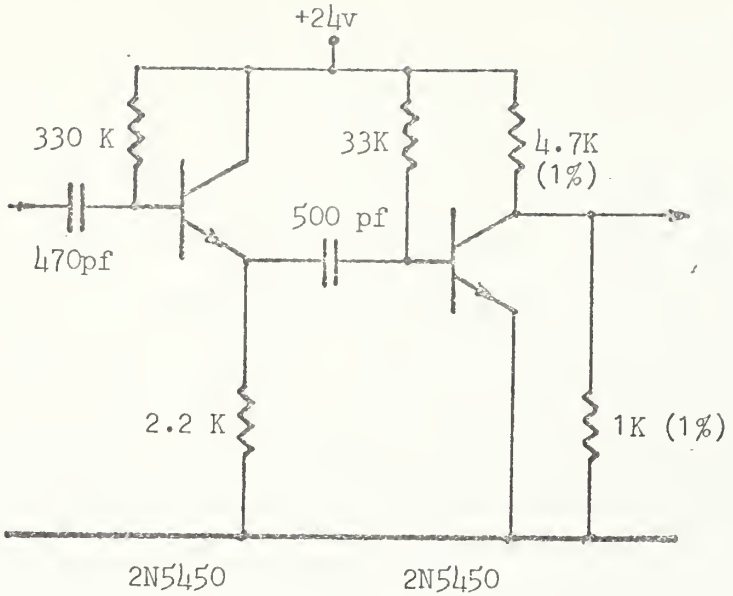


Figure 12. Circuit diagram of clock pulse generator

The output of this circuit is a pulse train which consists of 20 individual pulses. The pulse period is 0.7 microseconds. The pulse width and the spacing between pulses are equal to each other, 0.35 microseconds. These are nominal values which can be increased or decreased by changing the oscillator frequency. The repetition period of the pulse train is equal to the radar pulse repetition period (1250 microseconds). The pulse width and the spacing of the individual pulses can be varied by the variable inductor in the oscillator circuit.

These pulses are applied to the shift registers and the one-shot multivibrator as clock pulses. The output of the one-shot multivibrator is a pulse having a pulse width longer than 14 microseconds (in this particular circuit it is adjusted to 20 microseconds by an appropriate capacitor and resistor combination). The output of this multi has a 0.5 microseconds rise-time delay. Since the reference is zero volts, this delay was used to load the shift registers with "high" (logical "1")

voltage. When this output of the multi becomes high, the loaded logical "1" starts shifting with each successive bit.

The parallel outputs of the shift registers are inverted to provide successive gating pulses for each channel. The output pulse of each channel is a 0.7 microsecond long, jitter-free negative going pulse which is used as the gating pulse for the corresponding sample-and-hold and video-reconstructor circuits. Each successive gate pulse is one pulse width delayed from the previous one so that equal gate intervals are provided by the MTI circuitry. The wave forms at important points in this circuit are shown in Figure 14.

Three supply voltages are required for the MTI circuits, +24, +5, and -24 volts.

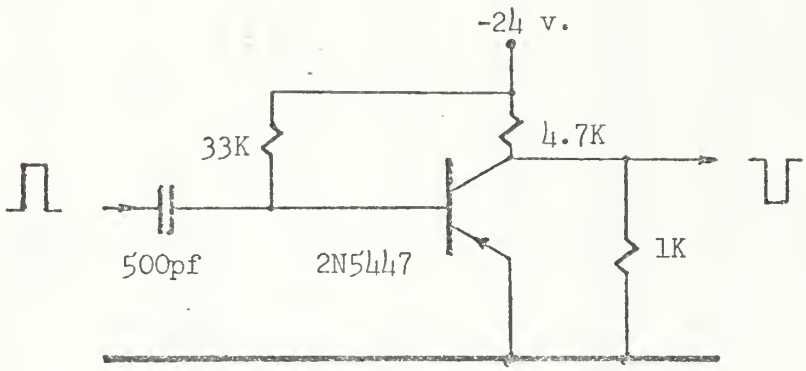


Figure 13. The inverter circuit

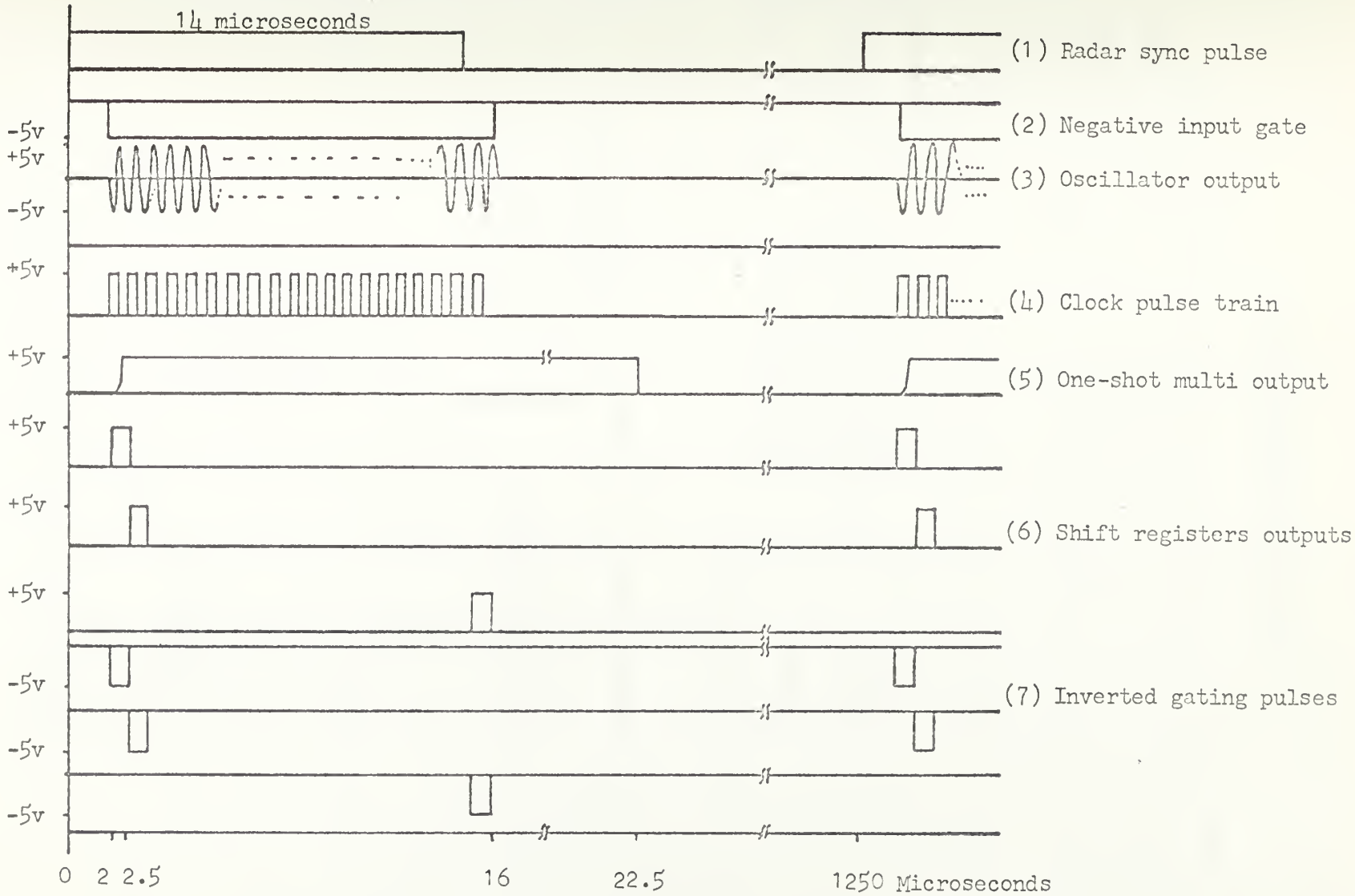


Figure 14. Waveforms in the timing circuitry

V. RADAR-SIMULATION TEST SET-UP

The block diagram for radar simulation used in initial testing is shown in Figure 15. A function generator was used to simulate the moving-target video. Waveforms at various points were observed on an oscilloscope. The experimental data and the waveforms are given in the next section.

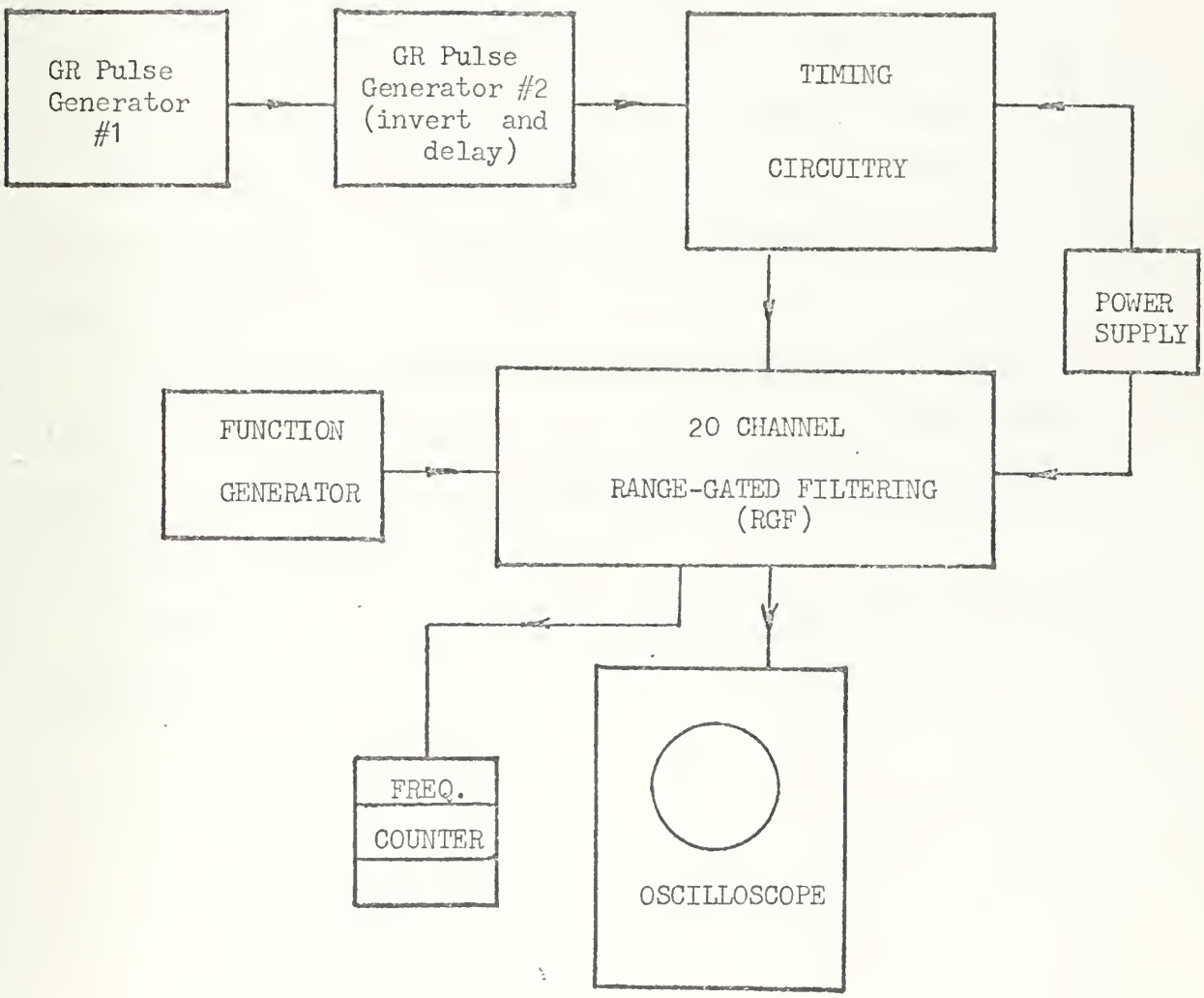


Figure 15. Radar-simulation test set-up

VI. EXTENDABILITY

Extendability of the system has been provided by constructing the circuits on printed circuit boards. Future improvements and simplifications may be incorporated by modifying individual plug-in circuit cards. Additional channels may be incorporated by adding circuit cards.

For a complete radar processor with many more than 20 channels, and multiple copies of the radar, special purpose integrated circuits could be constructed to perform the various functions. Cost, size, and power consumption could be reduced with such mass-produced integrated circuits.

Various types of active and digital filters with variable passbands can be substituted in each channel. Some suitable filter types are mentioned in references (3) and (7).

A Schmitt-Trigger integrated circuit could be used in place of the discrete square pulse-forming circuit. By using IC transitor array chips for inverting the output pulses of the shift registers the size of the timing circuit could be reduced.

Additional shift registers may be added if operation of more than 20 channels is desired.

VII. RESULTS

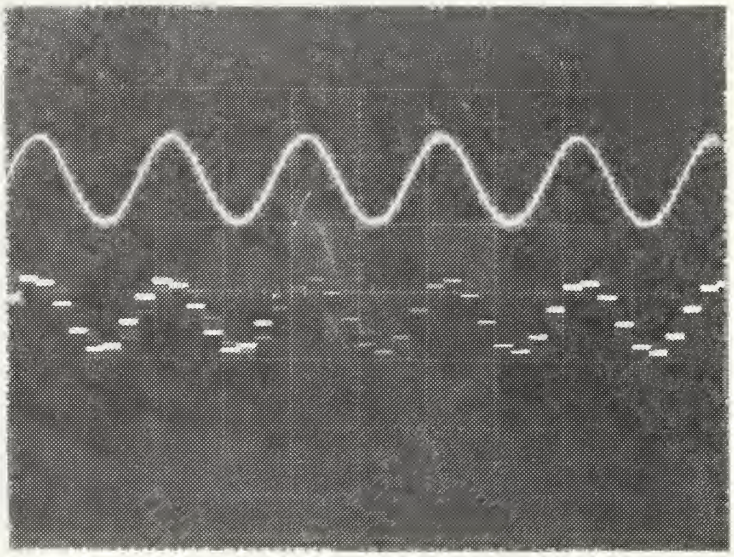
First, one complete range channel was constructed and tested for performance. Necessary modifications were made on this channel. Then four additional channels were constructed and tested. Certain additional improvements and simplifications were made until a satisfactory result was obtained. These channels were tested in the set-up shown in section V. By use of the General Radio pulse generator an adjustable delay trigger was applied to the system so that the twenty channels could function at any desired range.

The sample-and-hold circuit was tested and found to perform satisfactorily to the maximum video frequency. Figure 16 shows the output of one of these circuits for a 100 Hz sine wave and for bipolar video input.

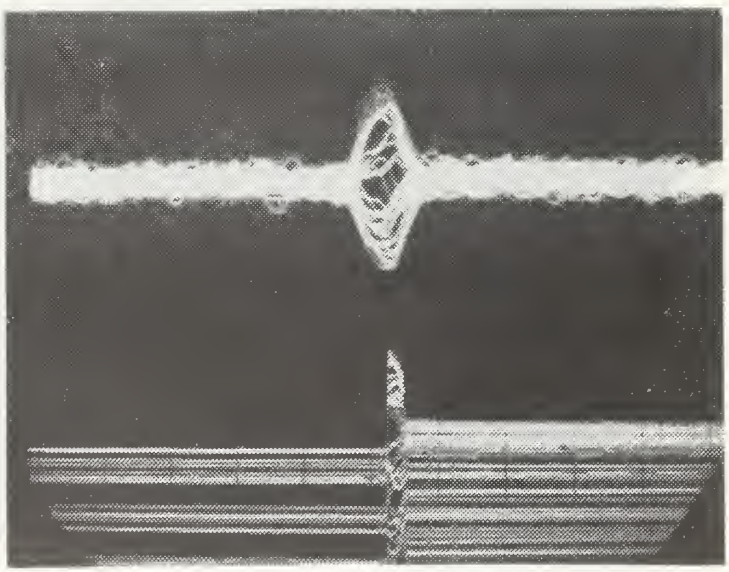
Figure 17 shows the output of the same channel filter circuit for 100 and 800 Hz sine wave. It is seen that unwanted frequencies are essentially eliminated.

Figures 18, 19, and 20 show the performance of the output circuit in the same channel. A very clear positive going output pulse was obtained for that range interval of the incoming signal. The amplitude of the pulse varies depending on the amplitude of the incoming signal.

Similar performance was achieved from all the other range channels. Figure 20 shows the output response of the 20-channel system to a 100 Hz since wave input. It is seen that all channels have essentially equal gain.

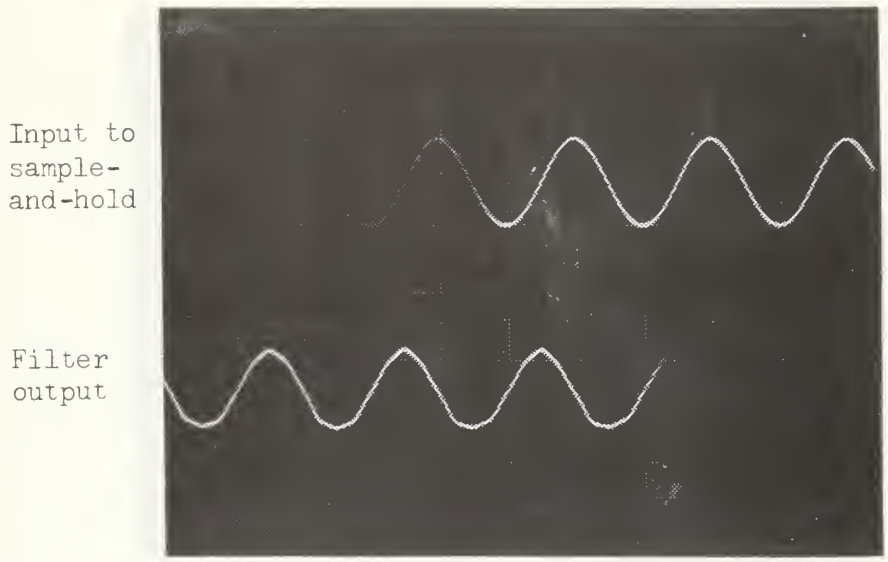


(a) 100 Hz sine-wave input

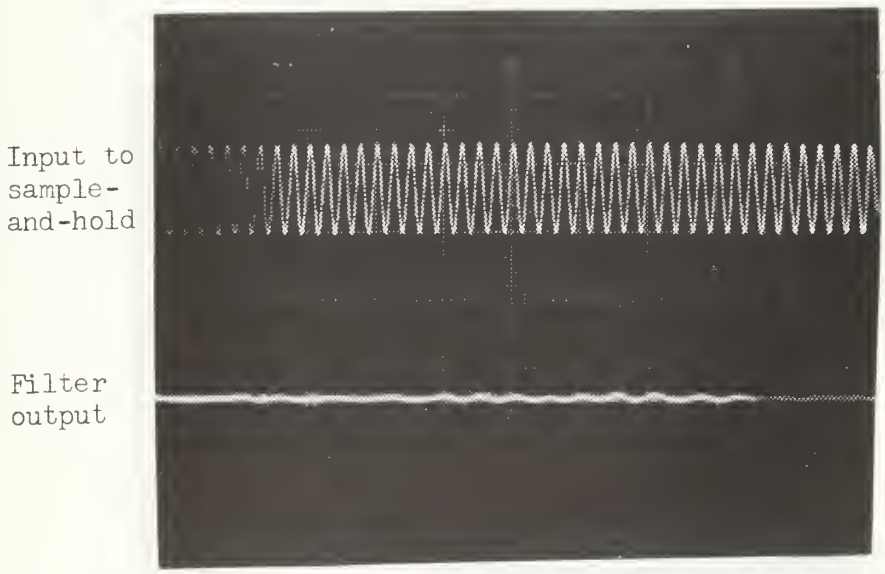


(b) Biopolar video input from AN/UPS-1 radar

Figure 16. Sample-and-hold circuit operation, one channel.



(a) 100 Hz input



(b) 800 Hz input

Figure 17. Doppler filter operation

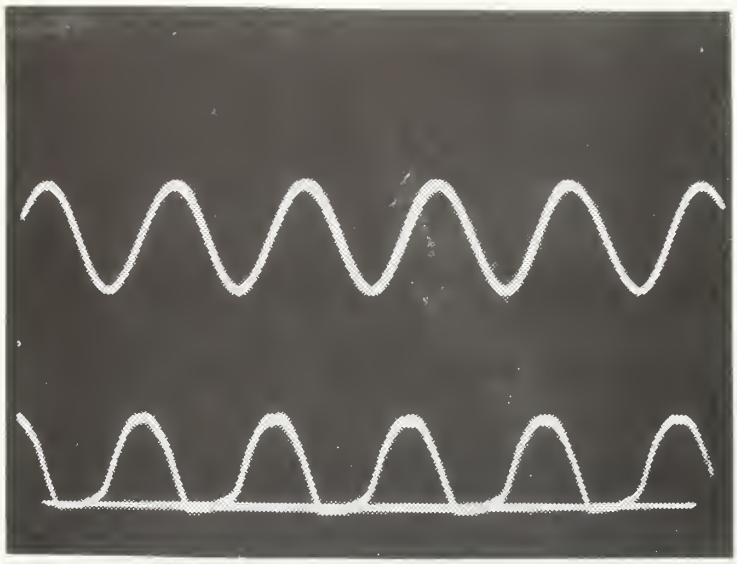


Figure 18. Detector output (lower trace). The 100 Hz sine-wave input is shown in the upper trace.

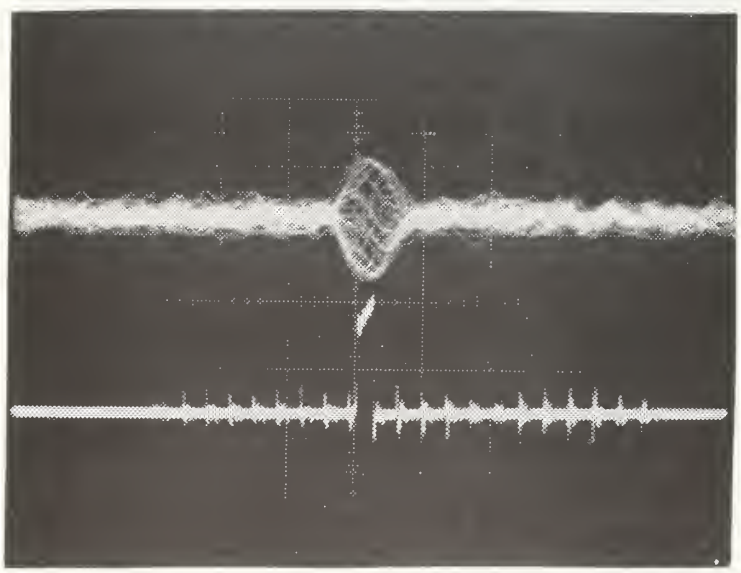


Figure 19. Integrator output, one channel (lower trace). The bipolar video input to the system is shown in the upper trace.

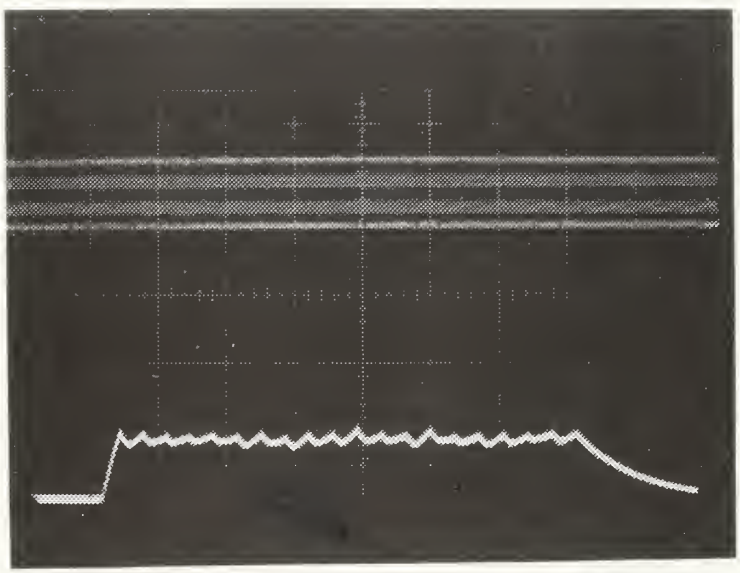


Figure 20. Output of the video reconstructor circuit (lower trace) with a 100 Hz sine wave system input (upper trace).

The band-pass filters were tested for a frequency range of zero to 800 Hz. The characteristic filter response is shown in Figure 21. The response was as desired.

The response characteristics of the output circuit is shown in Figure 22. Output follows the input very linearly. The maximum output amplitude obtained is +2 volts.

Next the entire system was tested in conjunction with the AN/UPS-1 radar. The operation of the timing circuitry in synchronization with the radar was excellent.

As it is seen from the Figures 23, 24, and 25 the outputs of the oscillator and the clock pulse-forming circuits were jitter-free and satisfactory for obtaining the gating pulses from the shift registers.

The outputs of the first three channels of the shift register are shown in Figure 26. These pulses were inverted and used as gating pulses as shown in Figure 27.

The overall system response to a moving target echo is shown with two different time scales in Figure 28. System response to the noise and clutter was much better than the MTI delay-line canceler as shown in Figures 29, (a) and (b). Figure 30 shows the system response to a moving target hidden in clutter.

A Hewlet-Packard video amplifier was used as a buffer between the radar coherent video output and the input of the range gates. This amplifier served to provide isolation between the radar and the range-gated MTI circuitry.

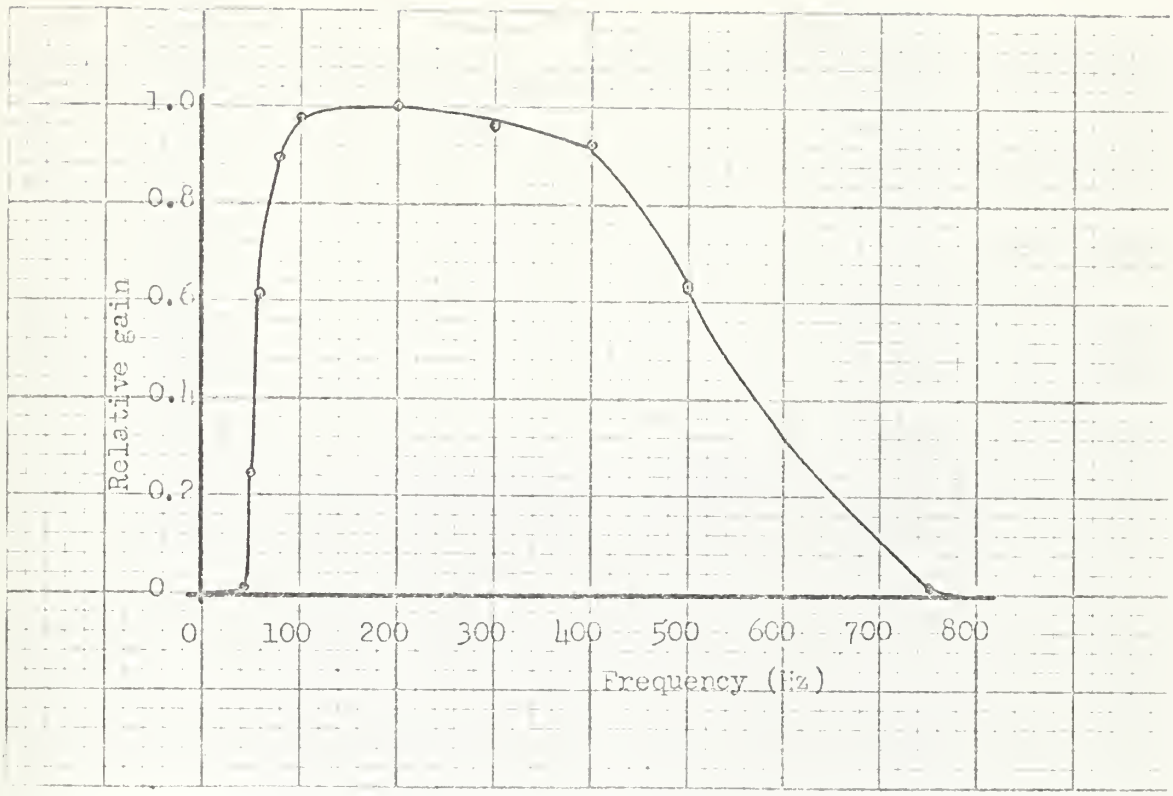


Figure 21. Frequency response of the filter

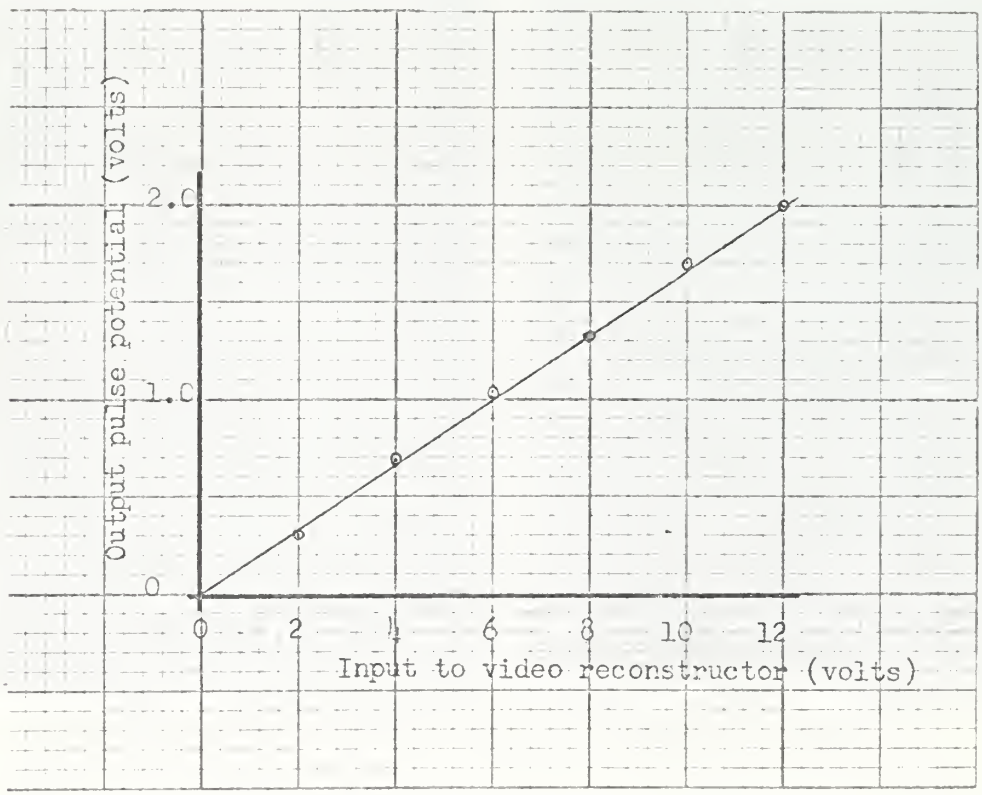


Figure 22. Linearity of the output circuit

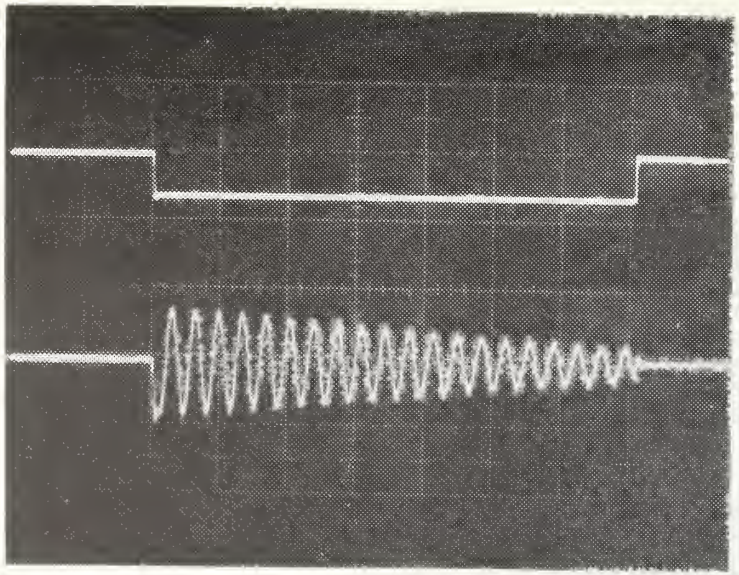


Figure 23. Oscillator operation. The upper trace shows the oscillator gating pulse, the oscillator output is shown by the lower trace.

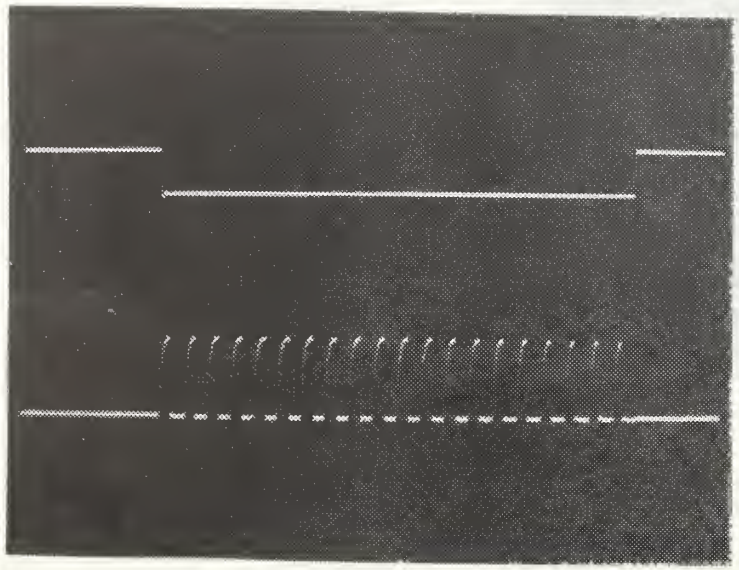


Figure 24. Square pulse generator operation. The upper trace shows the oscillator gating pulse, the lower trace shows the generator output.

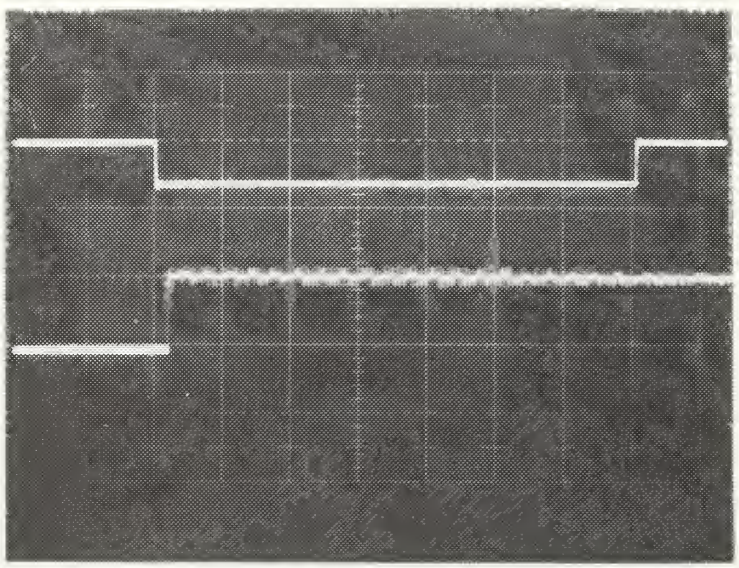


Figure 25. One-shot multivibrator output, lower trace. The upper curve is the 14 microseconds long negative input gate. 0.5-microsecond delayed output of the one-shot multivibrator is shown by the lower trace. The writing rate is 2 microseconds/cm.

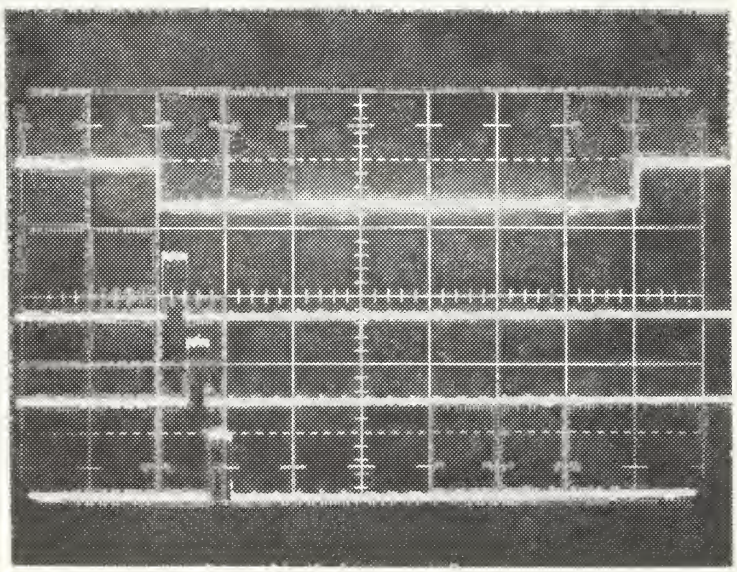


Figure 26. Output of the shift registers. The upper trace shows the negative input gate. The lower three traces show the first three gating pulses before inversion.

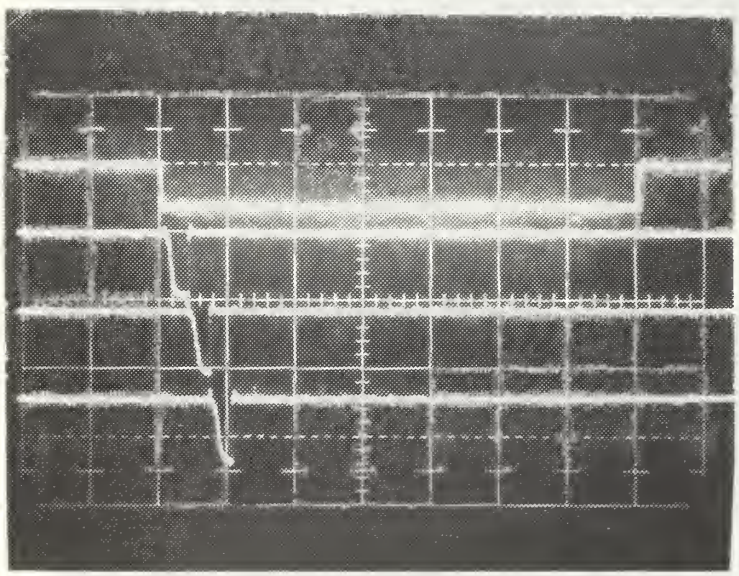
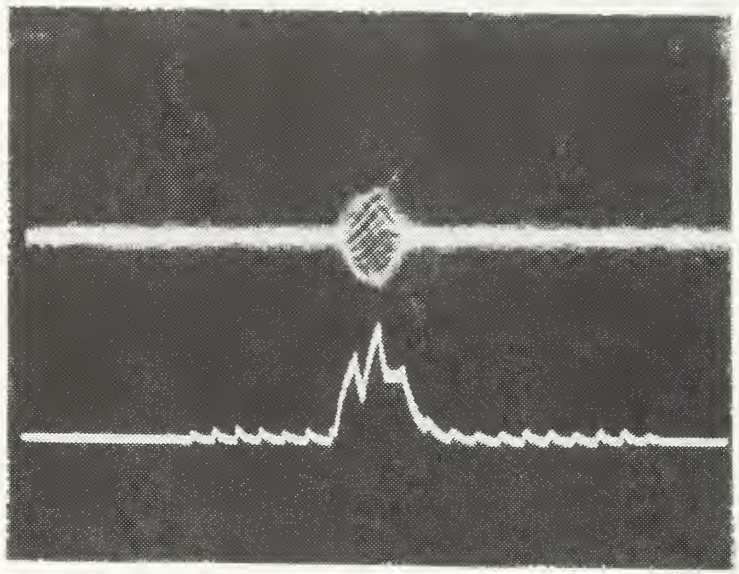
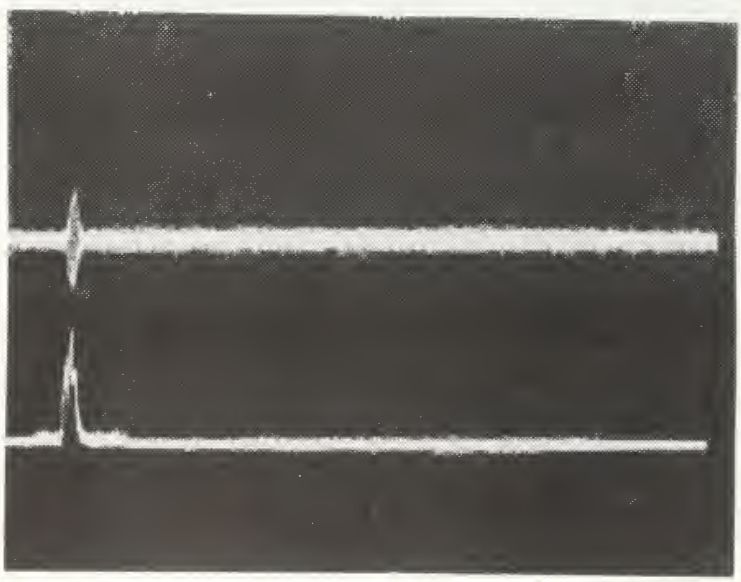


Figure 27. Gating pulses. The upper trace shows the negative input gate pulse to the timing circuitry. The lower three traces show the first three gating pulses after inversion.

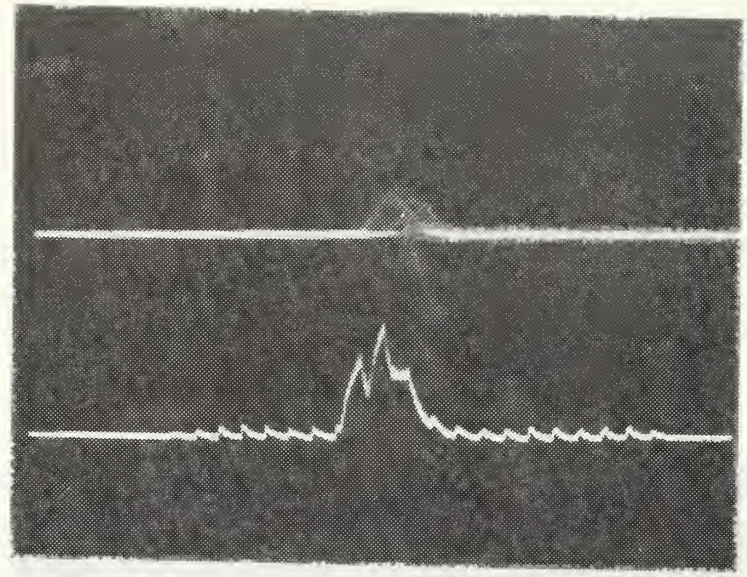


2 microsecond/cm

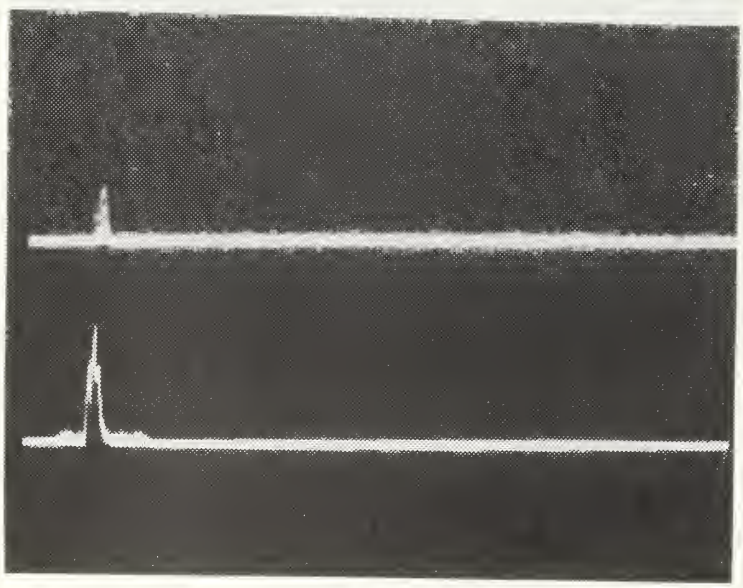


10 microsecond/cm

Figure 28. Overall system operation. The upper trace in each case is bipolar video with a synthetic moving target. The lower trace is the reconstructed video output. The writing rate in the upper photograph is 2 microseconds/cm, and in the lower photograph is 10 microseconds/cm.

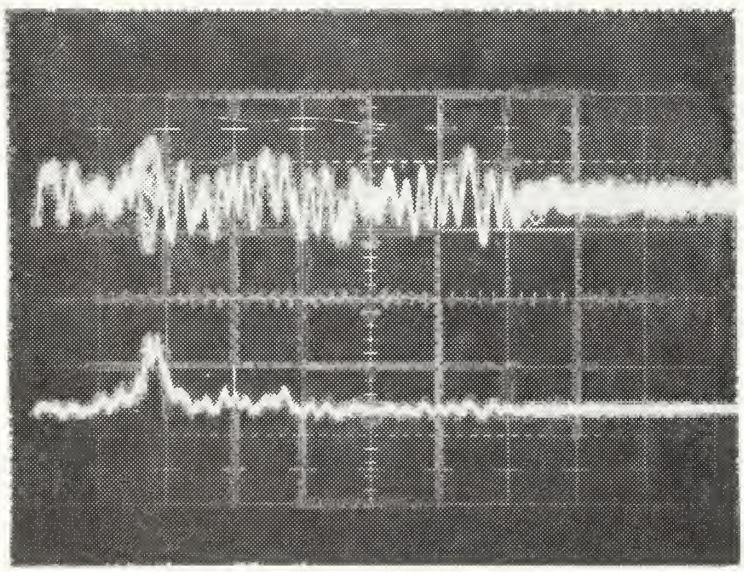


(a)



(b)

Figure 29. Comparison between the radar delay-line canceler and the range-gated MTI.
(a) Horizontal time scale 2 microseconds/cm.
(b) Horizontal time scale 5 microseconds/cm.
The upper trace in each case is the delay-line canceler output, while the lower trace shows the range-gated MTI video output. In each case the moving target is synthetic.



5 microseconds/cm

Figure 30. Range-gated MTI response (lower trace) to a synthetic moving target hidden in clutter (upper trace).

To smooth the video signal the reconstructed signal output was integrated using an R-C integrator with a time constant of 0.7 microseconds. The output of this integrator was then amplified by using a second video amplifier. This scheme helped to smooth the video signal and gave a more satisfactory output.

Measurement of sub-clutter visibility gave approximately 20 dB for the delay-line canceler, while it was measured and determined to 22 dB for the RGF system.

Minimum discernable signal was measured and determined to -104.3 dB for the delay-line canceler and -106 dB for the RGF system.

VIII. CONCLUSIONS

As previously pointed out, several successful MTI systems employing range-gated filtering and timing circuits have been constructed and tested. The purpose of this work was to improve, simplify and modify the range channels, to design reliable, jitter-free timing circuitry, and combine and test these for successful operation.

Comparison of the improved range channels with the previously constructed circuits showed that considerable simplification and reduction in number of components and size have been accomplished and improvement has been made especially in both input and output gate circuits.

New timing circuitry was designed and constructed which provides gating pulses for twenty channels of range-gated MTI. The circuits can easily be extended for a larger number of channels. The use of integrated circuits was particularly helpful in achieving low cost, small size, and simplicity.

Thus the results were considered to be successful. They were also considered to be the proof of the simplicity and the effectiveness of this type of MTI.

Further improvements are of course desirable. In a complete system having, for example, 200 channels, the elimination of just one component per channel can result in a significant reduction in overall cost.

APPENDIX A: N74122 RETRIGGERABLE MONOSTABLE MULTIVIBRATOR WITH CLEAR

This monostable is designed to provide for the system designer complete flexibility in controlling the pulse width. The width can be lengthened by retriggering, or can be shortened by clearing. It has an internal timing resistor which allows the circuit to be operated with only an external capacitor, if so desired.

The output pulse width is primarily a function of the external capacitor and resistor. For C_{ext} greater than 1000 pf, the output pulse width (t_w) is given by

$$t_w = 0.32\ R_T\ C_{ext}\ (1 + \frac{0.7}{R_T})$$

where R is in Kilohm (either internal = 10 Kilohm or external timing resistor)

C_{ext} is in pf

t_w is in ns

These monolithic TTL retriggerable monostable multivibrators feature dc triggering from gated low-level-active (A) and high-level-active (B) inputs, and also provide overriding direct-clear inputs. Complementary outputs are provided. As shown in Figure 31 by triggering the input before the output pulse is terminated, the output pulse may be extended. The overriding clear capability permits any output pulse to be terminated at a predetermined time independently of the timing components R and C.

Pin connections are shown in Figure 32. The R and C values were calculated from the above formula. A truth table is given in Table II.

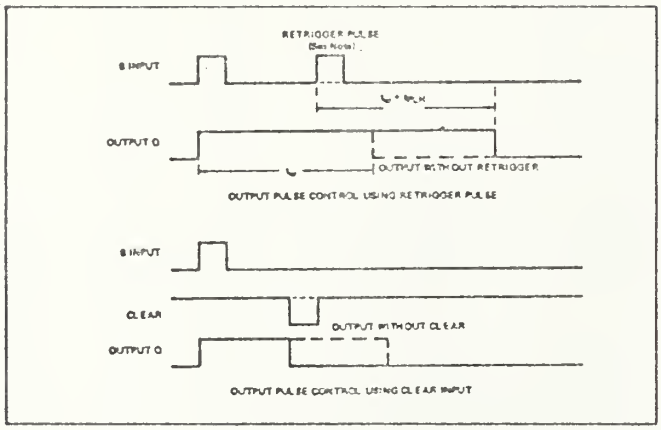


Figure 31. Typical input/output pulses waveforms

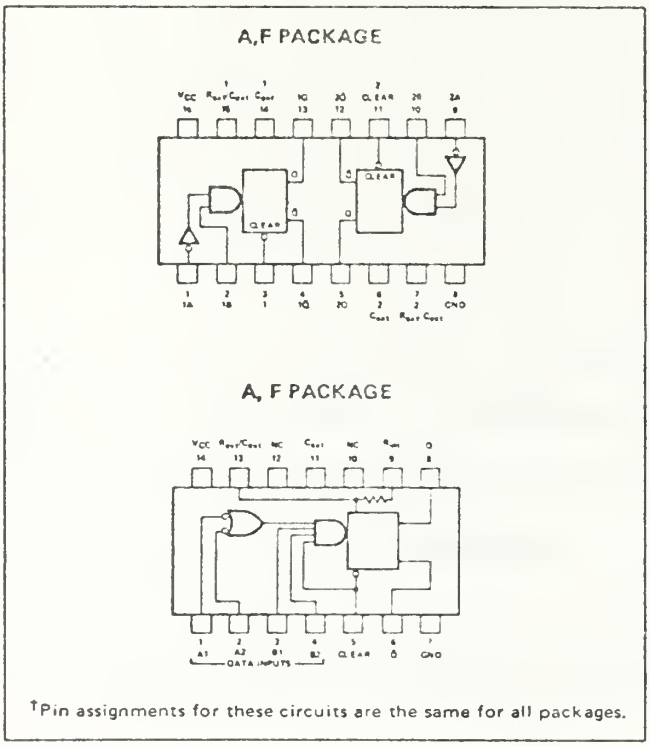


Figure 32. Pin connections

INPUTS				OUTPUTS	
A_1	A_2	B_1	B_2	Q	$\overline{Q}$
H	H	X	X	L	H
X	X	L	X	L	H
X	X	X	L	L	H
L	X	H	H	L	H
L	X	↑	H	⎍	⎵
L	X	H	↑	⎍	⎵
X	L	H	H	L	H
X	L	↑	H	⎍	⎵
X	L	H	↑	⎍	⎵
H	↓	H	H	⎍	⎵
↓	↓	H	H	⎍	⎵
	H	H	H	⎍	⎵

Table II. Truth Table of N74122

NOTES:

A. H = high level (steady-state), L = low level (steady-state), ↑ = transition from low to high level, ↓ = transition from high to low level, ⎍ = one high-level pulse, ⎵ = one low-level pulse, X = irrelevant (any input, including transitions).

B. NC = No internal connection.

C. To use the internal timing resistor of N74122 (10 Kilohm nominal), connect R_{int} to V_{cc}.

D. An external timing capacitor may be connected between C_{ext} and R_{ext}/C_{ext} (positive).

APPENDIX B: N74199 8-BIT SHIFT REGISTERS

These synchronous 8-bit shift registers feature parallel inputs, parallel outputs, J-K serial inputs, shift/load control input, a direct overriding clear line, and gated clock inputs. The register has three modes of operation:

Parallel (broadside) load

Shift (in the direction Q_A toward Q_H)

Inhibit clock (do nothing)

Parallel loading is accomplished by applying the 8 bits of data and making the shift/load control input low when the clock input is not inhibited. The data is loaded into the associated flip-flop and appears at the outputs after the positive transition of the clock input. During loading serial data flow is inhibited.

Shifting is accomplished synchronously when shift/load is high and the clock input is not inhibited. Serial data for this mode is entered at the J-K inputs. The J-K input truth table for states required to entered serial data into the first flip-flop, is shown on Table III.

Both of the clock inputs are identical in function and may be used interchangeably to serve as clock or clock-inhibit inputs. Holding either high inhibits clocking, but when one is held low, a clock input applied to the other input is passed to the eight flip-flops of the register. The clock-inhibit input should be changed to the high level only while the clock input is high.

INPUTS		OUTPUT
at t_n		t_{n+1}
J	K	Q_A
L	H	Q_{An}
L	L	L
H	H	H
H	L	$\overline{Q}_{An}$

Table III. Truth table of N74199

Pin configuration and connections for three of these shift registers are shown in Figure 33.

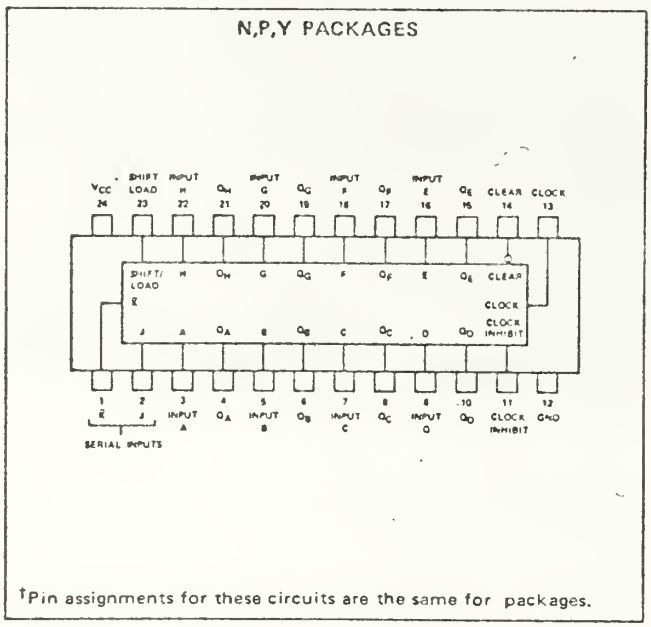
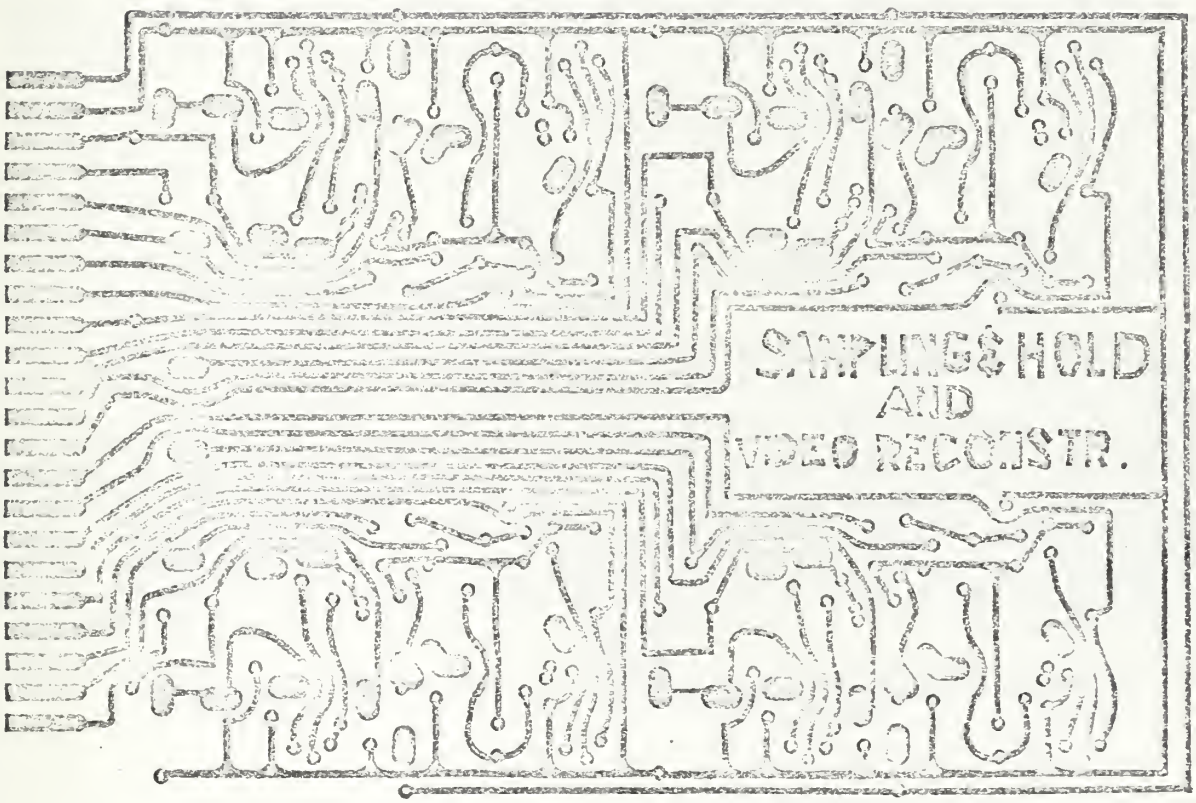
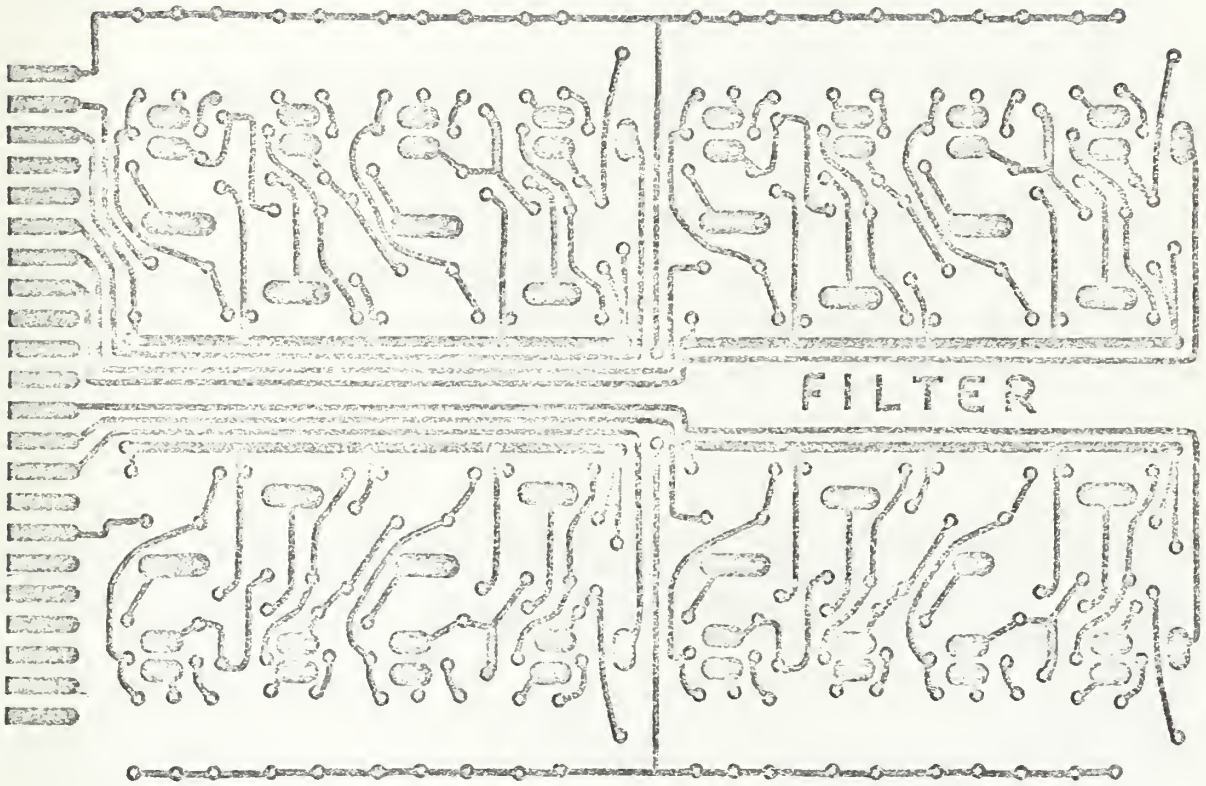
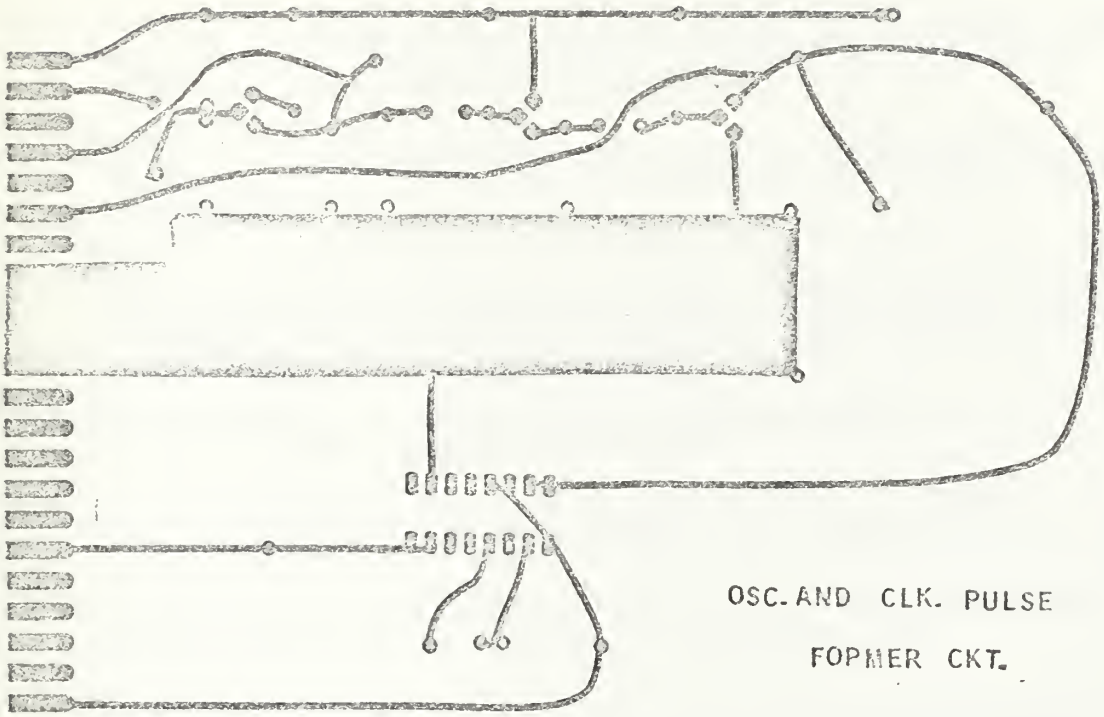


Figure 33. Pin configurations and connections of three registers.

APPENDIX C: PRINTED CIRCUIT DIAGRAMS




FILTER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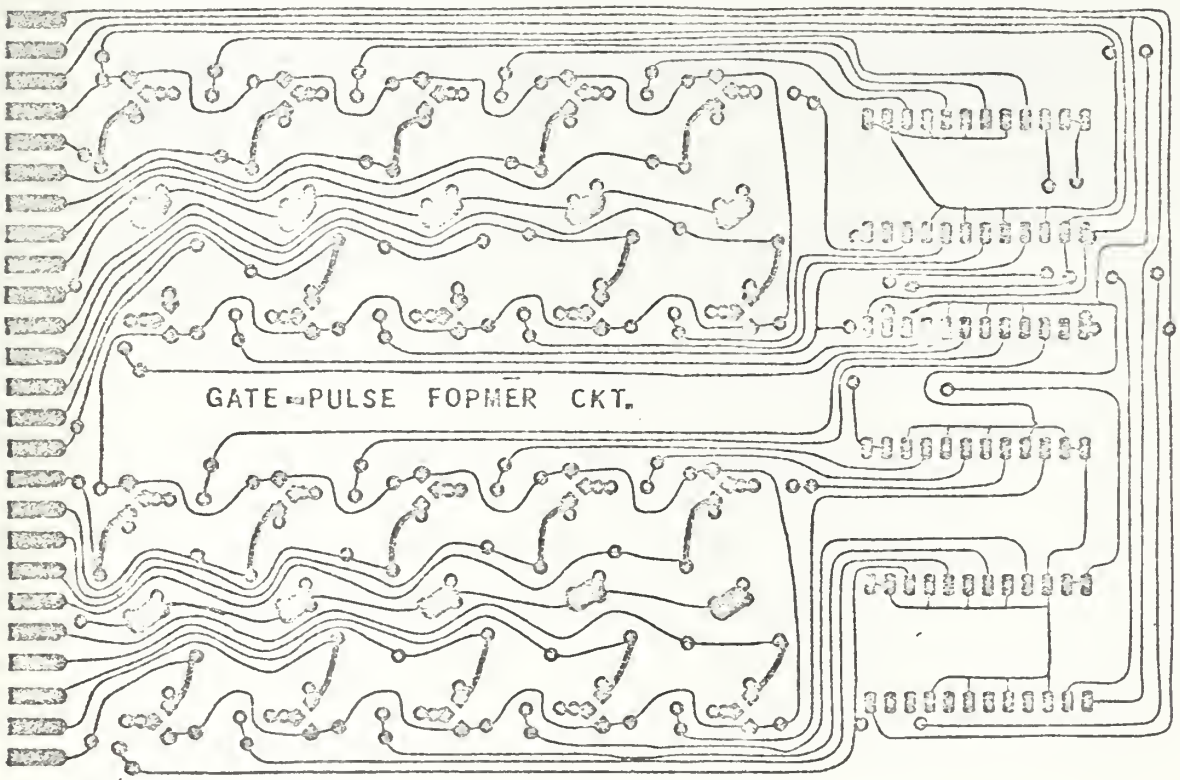
FOPMER CKT.


GATE PULSE FOPMER CKT.

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ABSTRACT

Twenty range-gated channels and the associated timing circuits were constructed for implementation of a moving-target indicator (MTI) by range-gates and filters (RGF). Improvement over existing systems was accomplished by simplification in the range-gated channels. Elements of the system include both discrete and integrated circuits. A design objective was to achieve reliable and jitter-free gating pulses with timing flexibility. Performance of the system was tested in conjunction with the AN/UPS-1 air search radar.

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MOVING TARGET INDICATOR						
RANGE GATING						

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K785 Koral
c.1
141297
Radar range-gated MTI
processor.

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20725
22828
23172
1 MAY 79
25203
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